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GREEK DISCOVERIES AND INVENTIONS

Some years ago two notable articles appeared in the Revue de Philologie. One of these was a review of Wilamowitz-Moellendorff's Greek Reader; the other was an editorial written as an accompaniment to this review. The burden of the editorial was that the study of Greek was in danger of being totally abandoned in France, and that perhaps a reproduction of the Reader for French pupils might contribute something to the maintenance of Greek, because the work contains numerous extracts which show that the ancient Greeks contributed much more to science and the mechanical acts than is generally known even to educated people. In so far as this implied (if it implied it at all) the abandonment of Greek as a literary study, it cannot be commended. That would be what the Germans call "Das Kind mit dem Bade ausschütten". Still it would make the study of Greek seem to the masses not so useless if they could be made to realize how much of our civilization, material as well as intellectual, has grown out of that of the Greeks. The Reader of Wilamowitz, however, is not at all suited to our secondary schools; but all our teachers of Greek, even professors in our highest institutions, should be familiar with it.

All fairly well educated people have some (though usually inadequate) conception of the influence exercised, directly or indirectly, by the Greeks, on the literature and art of the present civilized nations; but comparatively few seem to know how much modern science and the mechanical arts owe to them. There are, indeed, a few who believe almost literally that there is nothing new under the sun; while many who ought to be better informed claim almost all important inventions and discoveries for modern times. The truth lies between these extremes. A treatment of the whole subject would require a work of cyclopaedic proportions, and only a few illustrative examples will be cited in this paper.

In the Greek Reader of Wilamowitz some inventions are described in an extract from Hero of Alexandria. These are a slot-machine into which a coin was dropped which caused the flow of a little holy water; a sphere made to rotate by escaping steam (not a flutter-wheel driven by a jet of steam as has sometimes been stated); a hodometer, to be attached to a carriage and record the number of revolutions of the wheel. These are of little importance; but the fire-engine described in the same extract is practically the same as the hand-engine in use to-day. At Rome it was introduced in the early empire, and a large fire-brigade, supplied with such engines, was kept in readiness for conflagrations. In other parts of the work of Hero are mentioned the five elementary machines or "mechanical powers" as they are sometimes called. It is significant that Hero was much studied in the fifteenth and sixteenth centuries, and Wilamowitz says: "durch ihn hat das Hellenenthum den modernen Völkern die Begründung der neuen Physik und Mechanik ermöglicht".

The line between arts and sciences is not easy to draw. Some people think, for instance, that surgery and engineering are sciences. So no attempt will here be made to draw the line. In surgery, it may be noted, the ancient Greeks operated for cataract, displacing the crystalline lens with a delicate needle, and there are fragments extant telling *how to extract the lens,* but not necessarily implying that the operation had actually been performed. As to the influence of Greek medicine, it is sufficient to state the fact that, when William and Mary College (called Universitas Virginiensis in the pamphlet from which I get the information) conferred an honorary degree on the chief surgeon of Lafayette's army in the presence of George Washington, the surgeon responded in a long address urging the New World to cast the new medicine to the winds and stick to the good old medicine of Hippocrates and Galen.

But I must pass on to the sciences, and even here not only discoveries but also inventions are to be recognized. What was the greatest scientific discovery ever made? That the earth is round. The next discovery in order of interest is that the earth is simply one of the planets; but of that presently. Now that the earth is round is first stated by Aristotle; but his treatment of the subject shows that it was familiar to men of science. He gives several proofs of the rotundity of the earth. First, he says, it must be round, for if it were not, gravity would make it round. Secondly, the phenomena show that it *is* round. In Egypt, he says, you can see, to the south, stars that are under the horizon of any place in Greece; and the shadow of the earth cast on the moon during an eclipse is always bounded by a circle, no matter what the position of the moon. He adds that the earth is not a very large sphere, and that the mathematicians say it cannot be more than 400,000 stadia in circumference. This, of course, was a vague estimate. Eratosthenes, by measurement, made it, as everyone knows, 250,000 stadia, which is remarkably accurate in view of the fact that he used a well for a telescope. Also the round number is to be noted. (Very erroneous is the statement in certain text-books that 250,000 stadia amount to 31,250 miles. It is nearer 28,729; little more than one-tenth too large). The distance to the moon was also measured with equal accuracy.

The next most important discovery was that the sun is at the center of the solar system, or that the earth is a planet. This doctrine bears the name of Copernicus; but it was known to the ancients and defended especially by the Pythagoreans. Unfortunately Aristotle, not satisfied with the dogmatism of that school, arrayed himself against the doctrine, and long afterwards was followed by Ptolemy in the Almagest; and so the science of Astronomy was retarded for a millennium. Copernicus was familiar with all these facts. There are extant ancient works, maintaining the correct doctrine, with marginal notes made by Copernicus. Even the precession of the equinoxes was discovered by the ancients and estimated with great precision. The *cause,* of course, remained a mystery until Newton discovered the general nature of gravity. (The cause, gravity, still remains a mystery. We call it "gravitation", and sometimes we hear of the "attraction of gravitation", which Newton never called it).

Most of the facts stated above are familiar, some of them, in fact, being found in our elementary text-books of astronomy, but the chief object of this paper is to call attention to two almost universally ignored contributions of the ancient Greeks to the science of Mathematics. One of the most difficult subjects to treat adequately is the history of mathematics. Cantor's treatment of the mathematics of the Greeks is wholly inadequate, and I have had occasion elsewhere to call attention to one of his errors. The "specialist" selected to treat this subject for Müller's Handbuch says that for some unknown reason H instead of E was used to denote 100 in the old system, when the initial letter denoted numerals. In other words, this specialist did not known that in the fifth century B. C., H was the aspirate at Athens. He is a *mathematical* specialist, and no one can censure him. To treat this subject requires the collaboration of a mathematician and a Hellenist; and it is proper that I should explain why I venture to touch upon it. When I went to Germany I was in doubt whether to make the Classics my specialty, or Mathematics, for which as a college student I had a special fondness. So I conceived the idea of combining the two and writing my dissertation on the Greek mathematicians. After some months of research, it became evident that what I had in mind would require a large volume and years of labor, including a study of Arabic. In the meantime I had been surprised to find some things in the Greek mathematicians that are almost universally supposed to be modern. Since that time there has appeared a work just such as I had the ambition to write: Die Lehre von den Kegelschnitten im Alterthume, by Professor Zeuthen of the University of Copenhagen, translated from the Danish and published in German in 1886. If anyone is inclined to question the correctness of the statements I am about to make, let him first study Archimedes and Apollonius of Perge in the original and then the analysis contained in the work of Zeuthen.

The two most important steps in the progress of modern mathematics were the introduction of coordinate axes and of the infinitesimal calculus. To take these up in inverse order, I cannot go as far as Zeuthen and assert that Archimedes was familiar with and applied the integration of a differential equation (of course, expressed geometrically); but I do not hesitate to say that some of his processes, translated into modern notation, would be the integration of differential equations. This fact is specially notable in his method of finding the area of an ellipse and of a segment of a parabola. The process would suggest the invention of the (algebraic) calculus to very few minds, but it might well suggest it to a Newton or a Leibnitz. I have called the attention of mathematicians to this fact; but the reply usually is that, in finding the area of a parabola segment, he summed an infinite converging series, but that this is not integration. Of course it is not; but he found the area in two ways, and it is the other way to which I refer. A statement of it here would be entirely out of place.

As to coordinate axes the case is different. Descartes did not invent coordinate axes. They were familiar to him from the work of Apollonius of Perge on Conic Sections. The great contribution of Descartes, whereby he founded modern mathematics, was simply showing how by algebra we could perform the operations which Apollonius performed by what is called "geometrical algebra". With this assertion I must let the matter rest. I once called the attention of a mathematician, who had written a considerable series of mathematics, to the fact just stated, and, admitting that the ancients were familiar with projection, he utterly denied that they knew anything about coordinates.

By these allusions to mathematicians it is not in the least intended to reflect on mathematicians in general nor to imply that all or most of them are ignorant of the facts stated, but to produce a justification for this paper, intended as it is for teachers of the Classics. M. W. HUMPHREYS

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AENEID V

In a recent number of THE CLASSICAL WEEKLY (27) the statement was made that interest in the Aeneid lagged in the fifth book, and that other teachers are of the same opinion is shown by the fact that in some schools this book is omitted.

My experience, however, with successive classes of girls is, that not only interest may be aroused and attention held, but even enthusiasm often evoked. Indeed, the interest shown in the whole story seems wonderfully cumulative, reaching its